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<p>(54) Title: <b>DETECTION OF COUNTERFEITS OBJECTS, FOR INSTANCE COUNTERFEITS BANKNOTES</b></p>		
<p>(57) Abstract</p> <p>Detecting counterfeit banknotes is achieved by directing ultraviolet light at a sample from a source (104) and measuring the level of ultraviolet light reflected from the sample using a first photocell (105) and the amount of fluorescent light generated by the sample using a second photocell (106). The detected levels are compared with reference levels and only if both reflective and fluorescent criteria are satisfied is the note declared genuine. The sample, during test, is swiped over a glass window (102), preferably under an overlying shield.</p>		

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## DETECTION OF COUNTERFEIT OBJECTS, FOR INSTANCE COUNTERFEIT BANKNOTES

This invention relates to the detection of counterfeit objects. The invention will be described primarily in the context of the detection of counterfeit banknotes, but all  
5 aspects of the invention are applicable also to other documents, such as passports, cheques and trading stamps.

The production of counterfeit banknotes is continually increasing as a result of continuing improvements in printing technology, particularly colour printing. Counterfeit notes  
10 are now being made which appear, to the unaided eye, virtually indistinguishable from a genuine note.

It would be desirable to provide a device to assist a person conducting cash transactions, such as a shop assistant or bank teller, in verifying the authenticity of a received  
15 banknote. Such devices exist, but they rely for their operation on the experience and judgement of the user, and in any event are not very reliable. There are banknote discriminators which make numerous precise measurements to determine both authenticity and denomination of a banknote,  
20 but although these can be reliable, they are expensive, bulky and not suitable for use in, e.g., a shop where a customer's banknotes would have to be fully inserted into the machine before verification. The present invention seeks to provide a device which solves these problems, preferably by providing  
25 apparatus which can reliably be used to verify authenticity of banknotes held by a user without requiring accurate positioning and measuring techniques. However, the invention is applicable also to automatic discrimination devices, such as those in which the notes are fully inserted into a machine  
30 to enable measurements to be made.

Genuine monetary notes are now generally made to a specific formulation such as security or unbleached paper. Counterfeit notes, on the other hand, are generally but not  
always made from bleached paper. It is known to differentiate  
35 bleached from unbleached paper by viewing the paper under a source of ultraviolet radiation, such as an ultraviolet (UV) lamp which emits light having a wavelength which peaks in a

band of from 300 to 400 nm.

Bleached paper includes chemical components which fluoresce when exposed to ultraviolet radiation; that is, the molecules in the composition of the paper are excited and emit  
5 light at a longer wavelength which peaks in the band of from 400 to 500 nm. Because wavelengths of 300 to 400 nm generally lie outside the spectral region of the human eye and because wavelengths of from 400 to 500 nm lie within the spectral region, the phenomena of fluorescence allows some counterfeits  
10 to be detected with the human eye.

This process can be automated with the use of electronics by providing a sensor and a comparator which compares the intensity of the fluorescent light sensed with a reference level so as to provide an indication as to whether the paper  
15 is a likely counterfeit or not. Such an apparatus is disclosed in US Patent No. 4,558,224. However, some genuine money notes if washed acquire a deposit of chemicals which fluoresce and some counterfeit notes are made with paper containing little or no fluorescent materials and so the  
20 fluorescing phenomenon is not always an infallible way of deciding whether a note is counterfeit or not.

It is an object of this invention to provide an improved method and apparatus of detecting counterfeit objects.

According to one aspect of the present invention there  
25 is provided apparatus for detecting counterfeit objects comprising means for illuminating the object with light within a first wavelength band, a detector for detecting light from said object having a first wavelength within said first wavelength band and a second wavelength within a second  
30 wavelength band different from said first wavelength band and said second wavelength band including wavelengths at which counterfeit objects may fluoresce when exposed to light in said first wavelength band, comparison means for comparing the output of the detector with at least one reference level and  
35 decision means for deciding, based on said comparison whether said object is counterfeit or not and providing an appropriate indication.

According to another aspect of the present invention there is provided apparatus for detecting counterfeit objects comprising a detector for providing a first signal indicative of the reflectivity of an object within a first wavelength  
5 band and a second indicative of the fluorescence of the object within a second wavelength band different from said first wavelength band and decision means for deciding, based on said first and second signals, whether said object is a genuine banknote and for providing an appropriate indication.

10 Various further aspects of the invention are set out in the accompanying claims.

It has been discovered that genuine and counterfeit banknotes often have different reflectivities particularly when exposed to ultraviolet radiation in the band of from 300  
15 to 400 nm. It has also been discovered, somewhat surprisingly, that when the reflectivities of genuine and counterfeit notes are similar, the fluorescence exhibited by the notes is usually dissimilar, and vice versa. Thus by applying two tests to sense both the fluorescent light and the  
20 reflected light from a banknote exposed to ultraviolet radiation, a banknote can be declared genuine or counterfeit with great certainty.

The use of these techniques provides a surprisingly quick and effective way of detecting counterfeits. It has been  
25 found that no other measurements are needed, and consequently it is preferred that the indication of genuineness is given in response to measurements related only to reflectivity and fluorescence. Preferably, authentication is carried out on the basis of a single reflectivity value and a single  
30 fluorescence value, which are related to the whole object or a large area thereof. This, and the fact that discrimination between different denominations is unnecessary in a device intended for manual use by the banknote recipient, avoids the need for precise positioning of the banknote. However, the  
35 invention is applicable to other arrangements also; for example the technique may be used to supplement further measurements made in an otherwise-conventional banknote

validator.

Although reference is made herein to reflectivity measurements, it is believed that transmissivity could be measured instead or in addition thereto.

5       The techniques enable the construction of a simple counterfeit detector which is easy to use, e.g. beside a cash till. Preferred aspects of the invention are directed to enhancing the usability of the apparatus. Although these will  
10       be described in the context of an apparatus which employs the techniques mentioned above, they are considered independently inventive and could be applied to apparatus which does not employ such techniques.

According to a further aspect of the invention, apparatus for detecting counterfeit banknotes comprises a housing having  
15       a first part containing a radiation source and provided with a window enabling a sheet to be illuminated by the source, sensor means (preferably within said first part) responsive to radiation from the illuminated sheet for enabling a test  
20       to be performed to determine whether the sheet is a genuine banknote, and a shield overlying the window for reducing the amount of ambient light received by the sensor means.

The shield is preferably arranged so that a sheet can be held by the user of the apparatus, inserted between the shield and the window and then withdrawn therefrom without being  
25       released. If used by a shop assistant at the cash till, this would give greater confidence to the customer as the note is always seen to be visible and held while the testing operation is carried out. The gap between the window and the shield is therefore preferably open on at least two adjacent sides, and  
30       preferably on three adjacent sides so that the user can swipe the banknote into the gap via one side and out of the gap via the opposite side.

The gap between the shield and the window is preferably narrow (e.g. from 0.5 to 25 mm and preferably from 1 to 5 mm)  
35       to reduce the effect of ambient light, and preferably widens at least along one side of the shield to facilitate insertion. The widened opening may be for example at least 10, or

possibly at least 60 mm.

Preferably, the arrival of the note is automatically sensed so as to actuate the decision means. This automatic sensing could be achieved using one or more of the sensor or  
5 sensors used for the testing operation, or alternatively a separate arrival sensor could be provided.

Preferably, the machine is operable to give a first positive indication if the note is tested and found to be genuine, and a different positive indication if the note is  
10 tested and found to be counterfeit, so that the user knows when the test is finished. There is preferably also a third indication state, which is given when the apparatus is ready to receive and test a further note.

Use of these techniques enables the construction of a  
15 counterfeit detection apparatus which is simple, easy to use and relatively rapid in operation, enabling quick insertion of successive banknotes after each testing operation, which is reliable and which can be used while maintaining customer confidence.

20 Counterfeit detection apparatus embodying the invention will now be described, by way of example, with reference to the accompanying diagrammatic drawings, in which:

Figure 1 is a plan view of a first embodiment of the invention;

25 Figure 2 is a section taken on line 2-2 of Figure 1;  
Figure 3 is a section taken on line 3-3 of Figure 1;  
Figure 4 is a perspective view of a second embodiment;  
Figure 5 is an end view of the Figure 4 embodiment;  
Figure 6 is a block diagram of circuitry which can be  
30 used in the apparatus of Figure 1 or that of Figure 4;  
Figure 7 is a plan view of a third embodiment;  
Figure 8 is a side elevation of the third embodiment;  
Figure 9 is a schematic illustration of the circuitry of the third embodiment;

35 Figure 10 is a main flowchart illustrating the operation of the third embodiment; and

Figure 11 is a flowchart showing the authentication

routine performed by the third embodiment.

Figure 1 shows apparatus for irradiating a banknote with light and then measuring the amount of fluorescent light and reflected light.

- 5 As shown the apparatus includes a generally rectangular container 100 having a window 102 against which a banknote to be sensed can be placed. Within the container 100 there is provided an elongate light source 104 for producing light in the 365 nm region and directing it through the window 102.
- 10 Also within the container are two photo-diodes 105 and 106 spaced apart from one another but angularly inclined so that their optical axes intersect generally at the outer surface of the window 102. Each photo-diode 105 and 106 is mounted on the floor of a respective tubular opaque housing 108 and 110.
- 15 The inner walls of the housing are lined with reflective material to increase the sensitivity of the photo-diodes. A 365 nm band pass optical filter 112 covers the housing 108 and a 450 nm band pass optical filter covers the housing 110. The bandwidth of the filters is such that they do not overlap.
- 20 The lamp 104 is surrounded on three sides by reflective material 116, for example aluminium foil, which reflects light generally in the direction of the window 102 to concentrate the light at the window.

- Preferably the reflective material is so positioned
- 25 around the light source that the optical plane of the light directed at the window makes the same angle with the window as do the optical axes of the photo-detectors in a manner to ensure that the photo-detectors receive the maximum fluorescent and maximum reflected light from any banknote
- 30 placed on the window 102. Although it is preferred that at least the photosensor for the reflected light receive light from the source which has been specularly reflected, this is not essential.

- The window 102 is provided by a glass plate which
- 35 reflects some of the light received from the source 104 back to the photo-diode 105. The light is principally reflected back from the glass-air boundary of the plate and typically



is around 8% of the light directed at the glass plate.

When a genuine banknote is placed on the window the amount of reflected light at 365 nm is usually fairly small and so typically the amount of reflected light will increase from 8% to a value in the range of from 12 to 18%. Thus it will be seen that the light reflected from the plate when no banknote is present can be used as a reference level to compare the degree of reflection with when a banknote is present.

Thus any diminution in light output from the lamp due to ageing or any other defect is automatically compensated. Other errors are also eliminated because the light paths and components used to determine the reference level are the same as the light paths and components used to effect a measurement.

In the case of fluorescence the amount of fluorescent light emitted by a counterfeit banknote is generally several orders higher than the amount of light emitted by a genuine banknote and so any degradation of the light source 104 makes little or no difference to the detection of fluorescent light. Nevertheless, it has been found that improved operation may be obtained by using the detected fluorescence when no banknote is present as a reference level.

An electronic processor (not shown but which will be described in more detail hereinafter) monitors the light received by both photocells with the lamp 104 switched on. In the absence of a banknote on a window the photocell 105 will provide a steady state output. As soon as a banknote is placed on the window the output from the photocell 105 will rise and a trigger signal is then generated to activate two measurement circuits for measuring the outputs of the two photocells 105 and 106.

The measurement circuits provide readings which can be displayed by a display device 126, and a decision circuit will, in response to the readings, activate one of two optical indicators 122 and 124 respectively indicating that the banknote is genuine or counterfeit.

A printer (not shown) may be provided to record the values displayed by the display device 126.

It will thus be seen that the apparatus is automatically activated by the placement of a banknote on the window to  
5 determine whether the banknote is genuine or counterfeit.

Figures 4 and 5 show another embodiment, wherein like reference numbers indicate like elements. It is to be noted that any features described with reference to the first embodiment may be applied to this second embodiment and vice  
10 versa.

The embodiment of Figures 4 and 5 has a shield 400 located over the window 102 formed in the housing 100 which represents a base part of the structure. The shield 400 is spaced from the window 102 by a small distance  $d$  of, e.g. 0.5  
15 to 5 mm. As can be seen from Figure 5, the left, right and front sides of the shield 400 are open so that a user gripping a banknote can swipe it through the space between the shield 400 and window 102 from the left to the right side of the shield 400 without letting go. The left edge 402 of the  
20 shield 400 is curved upwardly to provide a widened entrance to the gap to facilitate insertion. The entrance gap  $D$  is preferably at least several times greater than the gap  $d$ , and may for example be 10 to 60 mm.

The housing 100 has a receptacle part 404 adjacent the  
25 right side of the shield 400 for receiving banknotes after they have been swiped past the window 102. There is a third indicator 406 which is illuminated when the apparatus is ready to receive and test a banknote. The indicators 122, 124 and 406 thus form an indication means having four indication  
30 states, and the apparatus may be operated as follows. When a shop assistant is handed a stack of bills, she passes them one by one through the gap between the shield and the window, each time waiting for the indicator 406 to be illuminated (indication state A). The indicator 406 ceases to be  
35 illuminated (state B) when the bill is detected. The indicator 122 is illuminated (state C) after successful testing and the bill withdrawn and placed in the receptacle

404. The next bill is then tested. If any bill is counterfeit, the indicator 124 is instead illuminated (state D).

The block diagram of Figure 6 shows the processor in more detail. The photocells as represented by the blocks 105 and 106 preferably include built-in amplifiers. Each feeds a respective trigger circuit 130 and 132 for detecting a rapid change in signal for example as a result of a banknote being placed on the window. Either or both trigger circuits 130 and 132 feed a signal to a gate 134 which, via actuator 140, actuates two measurement circuits 136 and 138 (for example by supplying power to them or deactivating inhibitors which inhibit their operation) and deactuates the indicator 406 (if present). A delay circuit in the actuator 140 deactuates the measurement circuits 136 and 138 after a short measurement period. A first comparator 142 compares the output of the photocell 105 with a reference value stored in a store 144 and an output dependent on the relationship between the detected value and the reference value is generated and is fed simultaneously to logic circuits 146 and 148. The signal stored in the store 144 is derived from the photocell 105 during the quiescent state of the apparatus. The output of the photocell 105 is amplified by an amplifier 150 by a factor of between 25% and 50% and stored in the store 144. As soon as the actuator 140 is triggered, the amplifier 150 is inhibited so that the store 144 only stores the quiescent value of reflected light. (In practice a delay circuit or similar may be provided so the quiescent value in the store 144 is not influenced by the increased output which triggers actuator 140.) A comparator 152 compares the output of the measurement circuit 138 with a reference value 154 and generates an output signal dependent on the relationship therebetween which is fed to the two logic circuits 146 and 148.

The logic gates 146 and 148 are enabled by the actuator 140 (via a delay circuit 156 to allow time for the measurements to stabilise). The logic circuit 146 responds

when a genuine note is detected to energise the indicator 122. Similarly the logic circuit 148 responds to energise the indicator 124 when a counterfeit note is detected. Relative to the dynamic ranges of the sensor circuits, it is expected that a genuine banknote will produce relatively low responses from both photosensors. Accordingly, if the comparators 142 and 152 compare their inputs with a simple threshold, the logic gate 146 may be arranged to produce an output only if each input indicates that the respective threshold has not been exceeded, and the logic gate 148 can produce an output in other circumstances.

Preferably, however, one or both of the comparators 142 and 152 is/are arranged to compare its input with upper and lower thresholds defining a window around a reference level and to produce one output if the input is between the thresholds and a different output otherwise. Thus, the apparatus may be arranged to determine a banknote to be genuine only if a (probably relatively low) level of fluorescence is detected and only if a (relatively low) reflectivity is detected.

The actual values at the outputs of the two measured circuits 136 and 138 are fed to the display 126 (if present) for display thereby.

If it is required to make more precise measurement of the fluorescence signal then it can be normalised to the reference level in the same way as the reflectance signal. The associated reference level may thus be dependent on the detected quiescent fluorescence or on the detected quiescent UV radiation.

After the indicator 122 or 124 has been illuminated, and the trigger circuits sense that the note has been withdrawn, the actuator 140 causes the indicator 406 to be illuminated again.

It will be appreciated that the value of the reference signals stored in the stores 144 and 154 can be adjusted as required. This could be done at manufacture during a calibration stage, or means may be provided for user-

adjustment. Switch means may be provided for altering the reference values to correspond with pre-stored references suitable for currencies of respective countries. If desired, the apparatus could be made self-calibrating by automatically  
5 adjusting one or more of the reference values so that they at least approximately track the actual measured values of notes determined to be genuine.

To reduce further the effect of ambient light the light source can be modulated at a selected frequency and the  
10 outputs of the photo diodes demodulated at the same frequency to eliminate the effects of ambient light.

The circuit of Figure 6 can be used either with the first-described embodiment, in which case the indicator 406 is not required, or the second described embodiment, in which  
15 case the display 126 is not required.

The size of the area of banknote from which radiation is received by the sensors 105 and 106 (which corresponds substantially with the window size) is preferably large, e.g. at least 6 cm<sup>2</sup> and preferably at least 30 cm<sup>2</sup>. Preferably,  
20 the size corresponds to at least 10% of the area of the notes to be tested. Sensing a large area of the banknote makes the measurements less dependent on positioning and alignment.

A third embodiment of the invention will now be described with reference to Figures 7 and 8, which show the structure  
25 of the embodiment, Figure 9, which schematically illustrates a circuit of the embodiment, and Figures 10 and 11 which are flowcharts illustrating the operation of the embodiment. Any of the features of the structure, circuit or flowchart can be implemented in either of the embodiments described above;  
30 similarly, any of the features described above could be incorporated in the third embodiment.

Referring to Figures 7 and 8, the embodiment has a housing 700 comprising a lower, base section 702 and an upper section 704. The upper section is supported at its rear  
35 (shown at the left in Figures 7 and 8) on the base section 702 in such a way that there is a gap 706 between the two sections, except for the region at the rear. As in the second

embodiment, the gap is intended to permit a banknote to enter therein for checking its authenticity. For this purpose, the base section 702 is provided at its top with a window (not shown) to allow measurements to be made on a banknote in the slot 706. The slot has a small height, e.g. 1mm, and the underside of the upper section 704 is non-reflective in the region of the window, so as to enhance the accuracy of the measurements. The window may for example be in the shape of a square, each side measuring approximately 40 mm.

10 A hidden hinge permits the upper section 704 to be pivoted upwardly about an axis shown at 708 to facilitate cleaning in the region of the slot.

On the upper surface of the upper section 704 there are a main display 710, which in this case is a bi-colour LED (i.e. it can be caused to display either a red or a green colour), holes 712 through which sounds from a speaker 714 (Figure 9) with a built-in amplifier can pass, a pushbutton 716, which acts as a volume control (successive operations switch between off, low, medium and high volume modes), currency indicators comprising three LEDs 718, 720 and 722 adjacent which are respective indicia 724, 726 and 728, and a currency-selector button 730. In the second and third embodiments, the internal structure of the lower base unit, including the arrangement of the light source, reflectors, window and sensors, may correspond to that of the housing 100.

As shown in Figure 9 (which illustrates only the relevant parts of the circuitry), these switches, LEDs and speaker are coupled via an input/output bus 732 to a controller formed by a microprocessor 734 which has internal ROM and RAM memories. The input/output bus is also connected to two control inputs of analog-to-digital converters 736 and 738 which are respectively arranged to receive outputs from sensors 105 and 106, corresponding to those described with reference to the earlier embodiments. The digital outputs of the analog-to-digital converters 736 and 738 are coupled via a databus 740 to the microprocessor 734.

Referring to Figure 10, when the apparatus is powered-up,

the program stored in the ROM of the microprocessor 734 starts at step 1000. After the apparatus is powered up, during step 1001, there is a delay period while the light source stabilises and during which the LED 710 is steadily illuminated to produce a red light. The light is switched off and the program then proceeds to step 1002. The apparatus then determines whether either of the pushbuttons 716 and 730 has been operated. If either switch is operated, appropriate action is taken at step 1004. If the pushbutton 716 has been operated, the current setting for the audio volume, as stored in a RAM location, is altered. Successive operations of the switch thus step through successive different volume modes. The pushbutton 730 is a currency-selection switch. This embodiment is capable of operating with any one of three different currencies (e.g. English, Scottish and Irish). Although the apparatus is not intended to discriminate between different denominations of a currency, the paper, ink and printing processes used for different denominations within a particular currency often have sufficiently similar characteristics that the same apparatus can determine authenticity for a plurality of denominations, so long as they are associated with a single currency. In this embodiment, the selectable currencies are indicated by indicia 724, 726 and 728, and operation of the pushbutton 730 causes the associated LEDs 718, 720 and 722 to light in succession. Accordingly, the operator merely presses the pushbutton 730 until the LED associated with his selected currency is illuminated.

The volume and currency settings may then be stored in a non-volatile memory (not shown) so that they are correct upon power-up.

At step 1006, the processor 734 causes the analog-to-digital converter 736 to read the output of the sensor 105. This is compared with a previously-stored value representing a measurement when no banknote is present. The amount by which the present measurement exceeds the previously-stored measurement is calculated. (Instead of taking the difference

between the present and the previously-stored measurement, the program may calculate a ratio.) At step 1008, if this amount exceeds a predetermined threshold, then it is assumed that a banknote is present, and the program proceeds to carry out an authentication operation indicated at step 1010 and shown in more detail in Figure 11. Otherwise, the program proceeds to step 1012, where the previously-stored measurement is replaced by the current measurement. The program then loops back to step 1002.

10       The authentication operation is shown in more detail at Figure 11, and starts at step 1100. This step is reached as soon as a user inserts a banknote. This would be done by swiping the note from left to right, as in the second embodiment, or by inserting the note toward the rear, to a reference surface, and withdrawing it from the front.

15       First, at step 1102, the program waits for a predetermined delay time. This may be for example around 20 mS, to allow time for the banknote to be fully inserted. A counter N is then set to zero, and the program proceeds to step 1104. Here, the program causes both the converter 736 and 738 to operate to take measurements from the respective sensors 105 and 106. The program then proceeds to step 1106, where the program waits for a brief delay period and then increments the counter N. At step 1108, the program checks to see whether the counter N has reached 15, and if not the program loops back to steps 1104 and 1106. In this manner, 15 successive reflectivity measurements and 15 successive fluorescence measurements are made. (The value 15 is preferably a variable which is alterable depending on, e.g. the range of countries in which the apparatus is to be used.)

30       At step 1110, the program checks the data associated with the selected currency. This data, which is stored in ROM, includes a measurement technique value, and four threshold values to be described below. The measurement technique value determines how the 15 measurements for each of reflectivity and fluorescence are to be processed. Depending upon the measurement technique value, the program will proceed either



to step 1112, or to step 1114. At step 1112, the highest of the reflectivity values and the highest of the fluorescence values are taken, and the rest are discarded. At step 1114, the reflectivity values are averaged, and the fluorescence values are averaged. It has been found that either of these two techniques might be the more reliable, depending upon the currency in question. The program proceeds then to step 1116. Here, the program will have a single value representing measured fluorescence intended to be representative of the banknote as a whole, and a single value representing measured reflectivity. The program calculates the ratio of those values to the respective previously-stored values. These two ratios are used as the final reflectivity and fluorescence measurements.

The above technique, which involves taking a plurality of readings and then performing a process to derive a single measurement, is preferred, because it makes the apparatus even less sensitive to position of the banknote. It also slightly increases the effective area of the banknote over which readings are taken.

At step 1118, the program compares the final reflectivity measurement with two of the threshold values mentioned above, associated with the selected currency. These are upper and lower thresholds, and the program proceeds to step 1120 only if the reflectivity measurement lies between these thresholds. Otherwise, the program proceeds to a step 1122, where the user is given an indication that the note has not been authenticated. For example, the LED 710 is caused to flash red twice, and the speaker 714 is caused to emit a loud alarm noise.

At step 1120, the program checks the fluorescence measurement against the other two thresholds associated with the selected currency, which represents upper and lower permissible fluorescence limits. If the fluorescent measurement lies between these limits, the program proceeds to step 1124, but otherwise the program proceeds to step 1122. If the program reaches step 1124, this means that the banknote

has passed the authenticity test, and the LED 710 is caused to flash green once, and a short and audibly-distinct confirmation noise is emitted by the speaker 714.

After step 1122 or step 1124, the program proceeds to  
5 step 1126, wherein the reflectivity level is repeatedly measured by operating the analog-to-digital converter 736 until it declines to the threshold level mentioned above. There is then a short delay period to allow sufficient time for the banknote to have been completely removed, following  
10 which the authenticity routine finishes at step 1128.

In this embodiment, the final fluorescence measurement is based on both the currently-detected level of fluorescence, and a previously-stored reading which was taken when no banknote was present. To ensure that there is a sufficient  
15 level to obtain a reliable reading of fluorescence when no banknote is present, preferably the apparatus is provided with fluorescent material (not shown) which is sufficient to cause a measurable signal to be generated in the absence of a banknote. This material can be positioned within the lower  
20 section 702 of the housing, possibly on the underside of the window (in which case it needs to be small so as not to obscure a banknote inserted into the apparatus) or adjacent the window. A reference level generated predominantly in response to reflection from this fluorescent material is more  
25 stable.

In an alternative embodiment, the currency data can cause either averaging, or peak detection, or both, to be performed; in the latter situation there are derived two values for reflectivity (and/or fluorescence), each derived from the same  
30 readings and each representative of the banknote as a whole.

The above embodiment could also be modified by arranging for the processor to examine the differences between the measurements for reflectivity (and/or the measurements for fluorescence). The arrangement could be such that a banknote  
35 is rejected unless reflectivity (and/or fluorescence) measurements exhibit deviations exceeding a particular threshold. This operation may also be performed in dependence

on the data associated with the selected currency. This would avoid erroneously accepting counterfeits which exhibit overall the correct reflectivity and fluorescence characteristics, but which did not show the spatial variations expected of a genuine banknote.

In operation of the apparatus, the LED 710 has a number of states. A continuous red illumination indicates that the apparatus is warming up. No illumination indicates that the apparatus is ready to receive a banknote. A short green pulse indicates that the apparatus has completed its authentication and found the bill to be valid, and two red pulses indicates that authentication has been completed and the bill has been found to be a counterfeit. The apparatus is ready for use substantially instantaneously after the good/bad indication is given, so no further indication state is needed.

To a near approximation the following relationship applies:

$$r_s = (P_s/P_r) * r_g / (1 - r_g)^2$$

where  $P_s$  is the reflected portion of the irradiating signal from the specimen,  $P_r$  is similarly that portion returned from the glass plate to be used as a reference, and  $r_s$  and  $r_g$  are the coefficients of reflectance from the specimen and the glass plate. It will be noted that the effect of variation in  $r_g$  is negligible if small and significant if  $r_g$  is allowed to become large. Also that the relationship is inherently non linear and has been simplified to a first approximation. More precise normalisation could be carried out if required.

It has been observed that UV reflection from a banknote varies with the degree of soiling. It may be possible to measure the degree of soiling (e.g. by using an infra-red source and measuring the amount of radiation transmitted through the note) and to compensate by adjusting the reference values stored accordingly. Preferably at least most of the infra-red light path is the same as that of the UV radiation so that the response is also sensitive to soiling in other areas, e.g. on the glass plate. There could be a manual

switch which is operated when the user sees that a note is soiled to alter one or both reference values.

Additionally, or alternatively, the apparatus could be arranged to take a third measurement, of infra-red  
5 reflectivity (or transmissivity), and use the results in a similar way to UV reflectivity and fluorescence to determine authenticity. To be deemed authentic, the banknote would have to then pass all three tests.

The signal indicating a counterfeit note could be applied  
10 to a timer which produces a pulse of, for example, approximately one second which actuates an audible and/or a visual alarm. The output pulse from the timer may also or alternatively be applied to a line driver which is adapted to provide a suitable signal for application to a management  
15 system. This management system may be used to provide a warning to a remote control position, such as a manager's or security office in a shop for example, that a counterfeit note has been identified. Thus, as an alternative or in addition to the warnings at the point of sale (ie the till), management  
20 or security is discreetly informed. The line driver may, in one example, provide TTL signals.

It may be useful to be able to monitor the output of the lamp directly so that lamp degradation can be noted and thus the lamp replaced in good time. This may be achieved by  
25 applying the output from the sensor 105 (or another sensor receiving radiation from the source 104 irrespective of the presence of a banknote) to an input of a comparator. Another input of the comparator would receive a suitable threshold value. If the signal from the sensor becomes less than this  
30 threshold value then a signal is output from comparator to a warning means (e.g. audible and/or visual) to warn the operator to replace the lamp or one of its components.

Instead of making only one measurement of fluorescence it would be possible to make a plurality of measurements at  
35 different wavelengths using, e.g. different optical filters, and to base the determination of genuineness on the relative distributions.

In the above embodiments the measurements of reflectivity and fluorescence are separately processed to determine whether each is appropriate for a genuine banknote. Instead, the measurements could be combined (e.g. by multiplication or  
5 division), preferably after pre-processing at least one of them, and the result then tested to determine whether it is appropriate for a genuine note. For example, the difference between each measurement and a mean obtained by measuring a plurality of genuine notes may be squared, and the squares  
10 summed to obtain an overall measurement of the note.

Although it is preferred that the measured fluorescence be generated by the same UV source as is used for measuring reflectivity, a different source may alternatively be used.

It would be possible to modify the above-described  
15 embodiments so that only one sensor is used, e.g. by making the measurements in succession and switching filters.

The apparatus of the present invention may be embodied in a banknote counting machine for automatically counting notes in a stack and providing an alarm indication if a  
20 counterfeit note is detected. The apparatus may also be embodied in a safe box system provided with means for conveying notes to a safe, and testing each note before deposit. Alternatively, the apparatus could be attached to the side of a cash till.

## CLAIMS:

1. Apparatus for detecting counterfeit banknotes comprising a detector for providing a first signal indicative of the reflectivity of an object within a first wavelength  
5 band and a second signal indicative of the fluorescence of the object within a second wavelength band different from said first wavelength band, and decision means for deciding, based on said first and second signals, whether said object is a genuine banknote and providing an appropriate indication.
- 10 2. Apparatus according to Claim 1 wherein said first wavelength band is the ultraviolet light wavelength band and said second wavelength band is within the range 400 to 500 nm.
3. Apparatus according to Claim 1 or Claim 2 including a transparent plate for supporting a said object on one side  
15 thereof with the detector being located on the other side thereof and directed at the object through said plate.
4. Apparatus according to any preceding claim wherein said detector comprises first and second photocells each positioned to receive light from a said object and  
20 respectively arranged to be sensitive to light only in said first wavelength band and light only in said second wavelength band.
5. Apparatus according to Claim 4 as dependant upon Claim 3 including reference means for storing a first  
25 reference level which is a function of the light reflected by the plate in the absence of an object thereon and received by the first photocell, the decision means using the reference level in deciding whether the said object is a genuine banknote.
- 30 6. Apparatus according to Claim 4 or Claim 5 as dependant upon Claim 3 including means for illuminating a said object, wherein the optical axes of the photocells and the illuminating means converge upon that surface of the plate which is arranged to support a said object.
- 35 7. Apparatus according to any preceding claim including shielding means for shielding said detector from ambient light.
8. Apparatus according to any preceding claim including

control means for taking a plurality of readings of reflectivity of a banknote and a plurality of readings of fluorescence of the banknote, and for processing the readings to obtain a single reflectivity measurement and a single  
5 fluorescence measurement.

9. Apparatus according to claim 8, including means for selecting between first and second processing modes, in which the plurality of reflectivity readings and/or the plurality of fluorescence readings are processed in different ways.

10 10. Apparatus according to any preceding claim, including currency selecting means for switching said apparatus into different currency modes, whereby the criteria by which said first and second signals are treated as representing a counterfeit banknote are altered.

15 11. Apparatus according to Claim 9, including currency selecting means for switching said apparatus into different currency modes, whereby the criteria by which said first and second signals are treated as representing a counterfeit banknote are altered, said processing mode selection means  
20 selecting the processing mode on the basis of the selected currency.

12. Apparatus according to any preceding claim wherein said decision means comprises indication means for providing a first indication when the object is a counterfeit banknote  
25 and a second indication when the object is a genuine banknote.

13. Apparatus according to claim 12, wherein said indication means is operable to provide a third indication when the apparatus is ready to receive and test a said object.

14. Apparatus for detecting counterfeit banknotes, the  
30 apparatus comprising a housing having a base, a window in an upper surface of the base, a radiation source within the base for illuminating a sheet placed over the window and sensor means responsive to radiation received from the sheet so that a test can be carried out to determine whether the sheet is  
35 a genuine banknote, and a shield overlying the window in such a way as to allow the sheet to be inserted between the window and the shield, to reduce the amount of ambient light received

by the sensor means.

15. Apparatus for detecting counterfeit banknotes, the apparatus comprising a housing having a first part containing a radiation source and provided with a window for enabling a sheet to be illuminated by the source, sensor means responsive to radiation from the illuminated sheet for enabling a test to be performed to determine whether the sheet is a genuine banknote and a shield overlying the window for reducing the amount of ambient light received by the sensor means, the shield being separated from the window by a narrow gap sufficient to allow insertion of the sheet therebetween, the narrow gap having a relatively wide opening at at least one side of the shield to facilitate such insertion.

16. Apparatus claimed in Claim 14 or Claim 15, wherein the gap between the shield and the window is open on at least two adjacent sides, so that the sheet can be inserted from one side and withdrawn from another.

17. Apparatus claimed in Claim 17, wherein the gap is open on two opposed sides of the shield so that a note can be held by user while it is drawn across the window from one of the opposed sides to the other opposed side.

18. Apparatus for detecting counterfeit banknotes, the apparatus comprising a housing having a first part containing a radiation source and provided with a window for enabling a sheet to be illuminated by the source, sensor means responsive to radiation from the illuminated sheet for enabling a test to be performed to determine whether the sheet is a genuine banknote and indication means having at least three states, a first state being adopted prior to the results of the test being indicated, a second state indicating that the sheet is a genuine banknote and a third state indicating that the sheet is a counterfeit banknote.

19. Apparatus for detecting counterfeit documents, the apparatus comprising a housing containing a radiation source and a radiation sensor means, the arrangement being such that a user holding a document can transport the document along a path in proximity to the housing so that the document is



illuminated by the source and so that the sensor means receives radiation from the document, the sensor means being responsive to radiation from the illuminated document in at least two discrete wavebands for enabling a test to be performed to determine whether the document is genuine.

20. Apparatus according to Claim 19, wherein the sensor means is responsive to ultraviolet radiation and fluorescence generated in response to ultraviolet radiation.

21. Apparatus claimed in any one of Claims 14 to 20, wherein the sensor means is operable to detect radiation from an illuminated area of the sheet of at least 6 cm<sup>2</sup>.

22. A method of detecting counterfeit banknotes, the method comprising manually transporting a sheet past a source of ultraviolet radiation, taking a plurality of readings of reflected ultraviolet radiation and a plurality of readings of fluorescence as the sheet passes the source, processing the readings so as to obtain a first signal representative of the ultraviolet reflectivity of the sheet and a second signal indicative of the fluorescence of the sheet, and providing a signal indicating that the sheet is a genuine banknote if the first and second signals meet predetermined criteria.

23. A method as claimed in claim 22, including taking at least one infrared reading and providing the signal indicating that the sheet is a genuine banknote only if the first signal, the second signal and the infrared reading meet predetermined criteria.

24. Apparatus for detecting counterfeit banknotes, the apparatus comprising a housing having a window, means for illuminating a sheet which is moved past the window with ultraviolet radiation, first sensor means for detecting ultraviolet radiation reflected from the sheet, second sensor means for detecting fluorescence generated by the sheet, analog-to-digital converter means for converting the outputs of the first and second sensor means to digital values, processor means for deriving a first signal value representative of the ratio between the output of the first sensor means when a sheet is present and the output of the

first sensor means when no sheet is present, and a second signal value representing the ratio between the output of the second sensor means when the sheet is present and the output of the second means when no sheet is present, means for  
5 comparing the first signal value with first predetermined upper and lower threshold limits, and for comparing the second signal value with second predetermined upper and lower threshold limits, and means for providing a signal indicating that the sheet is a genuine banknote if the first signal value  
10 lies between the first upper and lower threshold limits and the second signal value lies between the second upper and lower threshold limits.

25. A method for detecting counterfeit documents, comprising:  
15 illuminating a test item with an ultraviolet light source;  
detecting light of a first wavelength with a detection means;  
generating a first signal indicative of the reflectivity  
20 of the test item;  
detecting light of a second wavelength with a detection means;  
generating a second signal indicative of the fluorescence of the test item; and  
25 deciding whether the test item is genuine based on the first and second signals.

26. The method of claim 25, further comprising:  
providing a visual indication if the test item is genuine.

27. The method of claim 25 or 26, further comprising:  
30 providing a visual indication if the test item is counterfeit.

28. The method of claim 25, 26 or 27 further comprising:  
providing an audio indication if the test item is genuine.

35 29. The method of any one of claims 25 to 28, further comprising:.

providing an audio indication if the test item is counterfeit.

30. The method of any one of claims 25 to 29, wherein each of said first and second signals represents  
5 characteristics of the document over a substantial area thereof.

31. The method of any one of claims 25 to 30, wherein the test item is illuminated through a transparent glass plate, further comprising: generating a reference level from  
10 the light reflected from the glass plate when no test item is present for comparison with the degree of reflection of a test item.

32. The method of any one of claims 25 to 31, wherein the step of deciding whether the test item is genuine  
15 comprises:

comparing the first signal to a first range of acceptable values;

comparing the second signal to a second range of acceptable values; and

20 accepting the test item as genuine if the first and second signals fall within the first and second ranges.

33. The method of claim 32, wherein the first range corresponds to relatively low levels of fluorescence.

34. The method of claim 32 or 33, wherein the second  
25 range corresponds to relatively low levels of reflectivity.

35. The method of any one of claims 32 to 34, further comprising:

adjusting the first and second ranges to approximately track the actual measured first and second signal values of  
30 test items determined to be genuine.

36. The method of any one of claims 25 to 35, further comprising:

generating a light source signal corresponding to the intensity of the output of the light source;

35 comparing the light source signal to a threshold value; and

activating a warning means if the light source signal is

below the threshold value.

37. The method of any one of claims 25 to 36, further comprising: modulating the light source at a selected frequency; and demodulating the detection means at the same  
5 frequency to reduce the effects of ambient light.

38. The method of any one of claims 25 to 37, wherein a plurality of measurements of fluorescence are taken for each test item.

39. A method for determining the genuineness of a  
10 banknote using an apparatus that irradiates the banknote with light and that measures the amount of fluorescent light and reflected light, comprising:

observing an indicator for a signal that the apparatus is ready to receive banknotes;

15 swiping a banknote through a gap defined by a shield, which blocks ambient light, and a substantially transparent window, through which light from a light source passes;

observing an indicator for a signal that the banknote has been detected;

20 accepting the banknote if an acceptance indicator is triggered; and

rejecting the banknote if a counterfeit indicator is triggered.

40. A method for determining the genuineness of a  
25 banknote using an apparatus that irradiates the banknote with light and measures the amount of reflected light and fluorescent light, comprising:

observing an indicator for a signal that the apparatus is ready to validate banknotes;

30 transporting a banknote past a transparent window through which light from a source passes;

observing an indicator for an acceptance signal; and  
accepting the banknote if the acceptance signal is given.

41. The method of claim 40, wherein the step of  
35 transporting a banknote past the window further comprises:

observing an indicator for a signal that the banknote was detected.

42. The method of claim 40 or 41, further comprising: observing an indicator for a counterfeit signal; and rejecting the banknote if the counterfeit signal is given.

43. An apparatus for validating banknotes which contains  
5 no moving parts, comprising:

a housing;

a transparent window connected to one side of the housing for supporting a banknote;

a light source contained within the housing;

10 at least one light detection means in the housing for sensing reflected light from the banknote falling within a first wavelength band and producing a first signal, and for sensing the fluorescent light emanating from the banknote falling within a second wavelength band and producing a second  
15 signal;

decision means connected to the light detection means for deciding, based on the first and second signals, whether the banknote is genuine; and

indicator means for indicating that the banknote is  
20 genuine.

44. The apparatus of claim 43, wherein the indicator means is operable also for indicating that the banknote is counterfeit.

45. The apparatus of claim 43 or 44, wherein the  
25 indicator means is operable also for indicating that the apparatus is ready to validate another banknote.

46. The apparatus of any one of claims 43 to 45, further comprising:

a substantially rectangular shield connected to the  
30 housing which lies in a plane over the transparent window, wherein the shield blocks ambient light from falling on the window and forms a channel with the window through which banknotes pass.

47. The apparatus of claim 46, wherein at least one edge  
35 of the shield is rounded to enlarge the opening leading to the channel.

48. The apparatus of claim 46 or 47, wherein the shield

is connected to the housing on one side such that a user may grasp a banknote during the entire validation process.

49. The apparatus of any one of claims 43 to 48, wherein the light source is modulated at a selected frequency and the  
5 output of the light detection means is demodulated at the same frequency to reduce the effects of ambient light.

50. The apparatus of any one of claims 43 to 49, further comprising:

10 a warning indicator for signalling that the light source has degraded.

51. Apparatus as claimed in claim 24, further comprising switch means for switching the apparatus between different currency modes, said first upper and lower threshold limits and said second upper and lower threshold limits being  
15 dependent upon the selected currency mode, whereby the apparatus is rendered suitable for different currencies, each including a plurality of different denominations.

52. Apparatus as claimed in claim 24 or claim 51, including fluorescent material which is arranged to generate  
20 fluorescence detected by said second sensor means, such that the output of said second sensor means when no sheet is present is predominantly dependent upon the fluorescence of said material.

FIG. 1

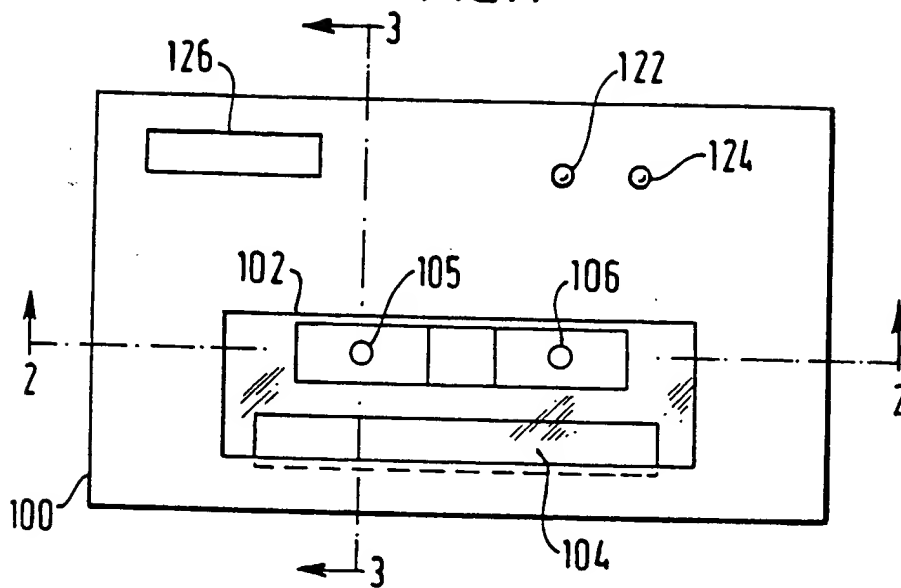


FIG. 2

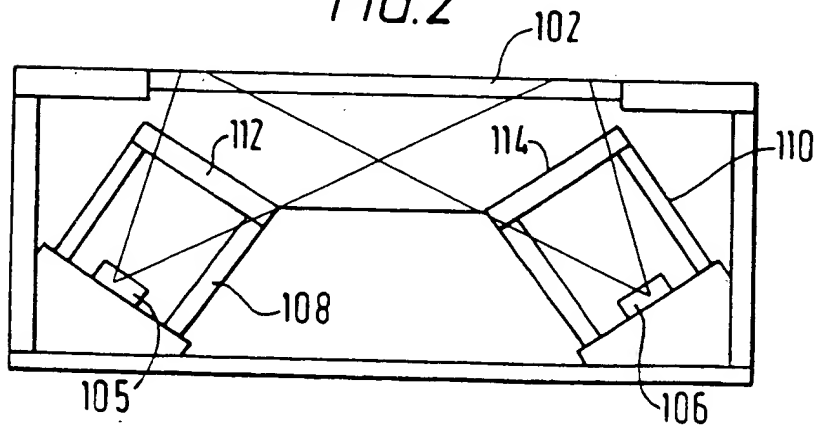


FIG. 3

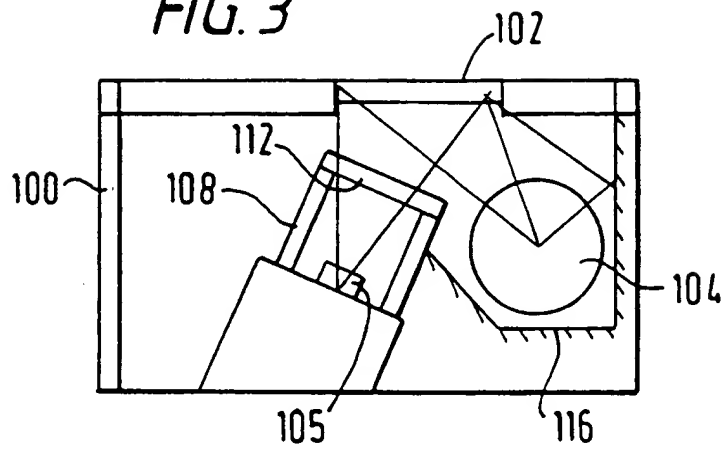


FIG. 4

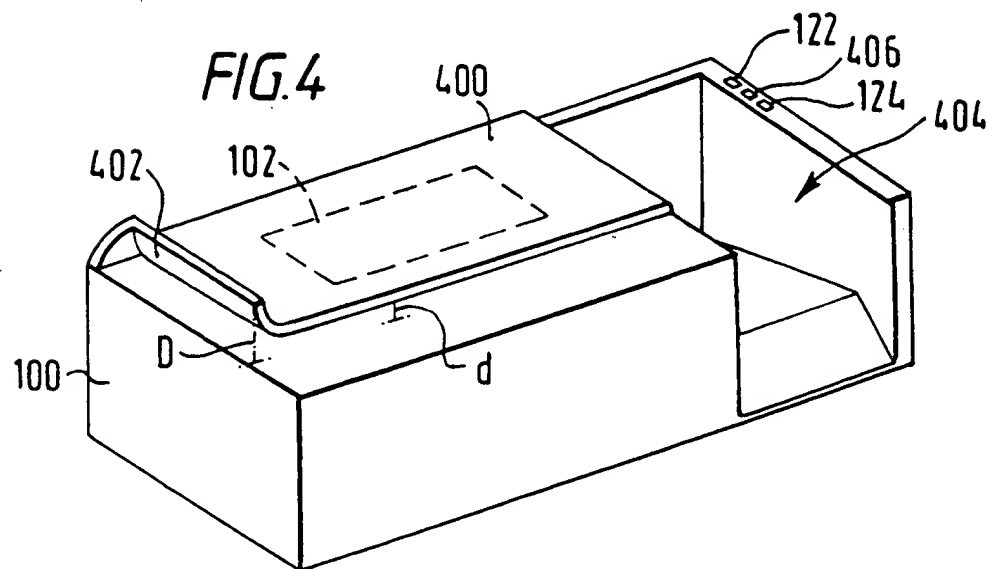


FIG. 5

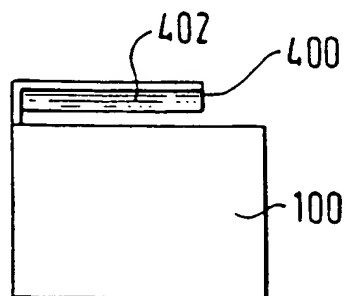




FIG. 6

